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THE HABITS OF THE STRIPED MEADOW CRICKET (*ŒCANTHUS FASCIATUS* FITCH).

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IN uncultivated wastes the common horse-weed (*Leptilon canadense* L.) often takes possession of the soil and flourishes most luxuriantly. Owing to its rapid growth, it not infrequently overshadows the neighboring clover, wormwood, knotweed, daisy fleabane, and other forms of plants which may happen to live where its society conflicts. There are many interesting features in the miniature forests of weeds, not the least of which is the insect life they harbor. In the last of August the weed first mentioned commonly attains a maximum height in sandy soil of from four to six feet, and it is at this period that it seemingly furnishes an ideal environment for the striped cricket *Œcanthus fasciatus* Fitch.[1]

My experience with this cricket (see Fig. 2), which is here related, is principally drawn from observations made at Lakeside, Michigan, during the month of August, the last day of September, and the first two days in October, 1904. Further studies

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[1] This cricket is commonly classed among the tree crickets, but it never or rarely lives on trees.

of its habits were carried out on numerous live individuals which I transported to my home in Chicago.

I have found this insect living singly, or from one to four together, upon the horse-weed, the females predominating during August. It is found more often on the main central stem, from eighteen inches to two and a half feet from the top, attracted there doubtless for the purpose of courtship and oviposition. Here it exhibits exquisite protective resemblance. The body of the insect is colored pale green, but the legs, antennæ, maxillary palpi, head, thorax, cerci, ovipositor, the ventral aspect of the thorax and abdomen, are very dark, though the color is somewhat variable. It is a delicate soft bodied insect, with exceptionally long antennæ. One of its favorite habits is closely to grasp the green main stem of its chosen plant with its body resting upside down. When disturbed, its first impulse usually is to jump to the ground, where its black legs, blending with the background of earth, are invisible, while the top of the body being green, now appears from above like a small blade of grass. If the insect is again molested while on the ground, it jumps quickly here and there in a spasmodic manner, then catching hold of some herbage climbs upon it. After waiting sufficiently long for danger to pass, the cricket eventually springs from one small plant to another until it again finds the main stem of the horse-weed. It then climbs up to take a position similar to that which it formerly occupied. One may often find it at rest, with its legs extended nearly straight out behind the body ; or it may appear on the flowers feeding. After a dry spell of weather in August, the older weeds, often selected as a residence by the crickets, present a series of dead brownish leaves below, that extend from the ground a third or more the length of the plants upwards. Because of the existence of these dead leaves and shadows, the darker parts as well as the light coloring on these insects serve as excellent protection. Moreover, as they rest on the main stem, among the maze of leaves they enjoy complete immunity from their grosser enemies. Later in the season the habits undergo some modification incident to the change in the vegetation. For instance, on September thirtieth, I visited the horse-weed patch which furnished the theme of the above narra-

tion, to find that many of the weeds, while still standing, had
turned brown and were dead.   There were very few crickets to
be found at the point where they had been so common before.
After a long search a number were located in quarters some-
what different from those in which I had previously found them.
They had taken up positions near the ground.   To enumerate, I
discovered one female hiding ten inches above the earth, within
a folded dead leaf of a ground cherry.   Close by was a male on
a green leaf of the same plant.   Immediately following these
observations, I found two more males and a female on the light,
yellowish green leaves of another of these plants.   Similarly,
a pair which were almost invisible were crouched among the
leaves and seed receptacles of a Potentilla.   On October first,
among some wild blackberry bushes, I noted a number of these
crickets of both sexes walking about on the upper surface
of the leaves.   The slightest motion on my part caused them
to seek safety by darting around the side margins of the leaves,
disappearing underneath, or they would jump below.   Here I
found two males near together clinging on upside down, each
hiding within a curled leaflet of the blackberry.   A stem of one
of these plants which I found here, shown in the reproduced
photograph (Fig. 1, *a*), shows ten punctures made by the oviposi-
tor of *fasciatus*.   The scarring of the plant in this way did not
appreciably affect the health of the branch, the leaves of which
were fresh and green.   The same day I located a number of
rather large plants of the golden-rod, the stems of which were
used by this œcanthid for depositing her eggs.   The points
selected for this purpose were often situated half way down the
main stem.   Here the darkened scar areas can be recognized
on the green stems where a number may be found lying in close
proximity.   The holes which are near together take the form
of vertical continuous lines of varying length, or they appear
dotting the surface irregularly, as shown in Figure 1, *b* and *c*.
A broken longitudinal section of the golden-rod at the scarred
places will show the eggs disposed in the manner represented
in Figure 1, *d*.   Or sometimes the eggs will be found missing,
and instead of them there will be encountered a white larva
which destroys the eggs.   This grub tunnels through the cen-
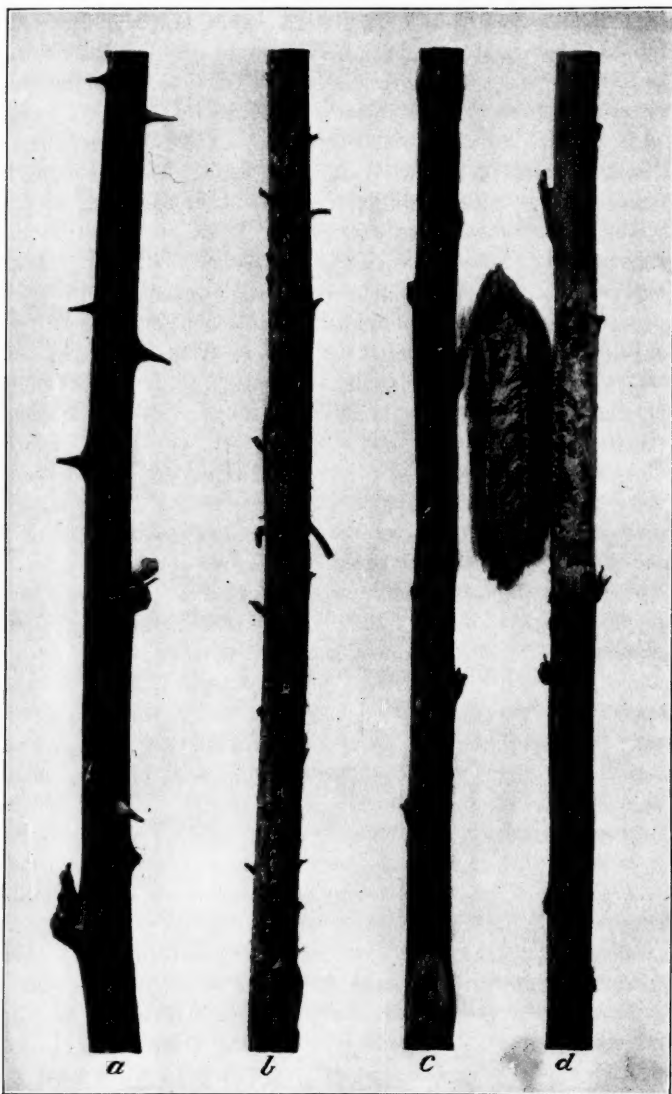tral pith, feeding on it and leaving the stems hollow.

FIG. 1. — Stems of the blackberry, *a*, the horse-weed, *b*, and the golden-rod, *c* and *d*, which have been stripped of their leaves to clearly show the holes made by *Œcanthus fasciatus* during oviposition. A portion of the stem *d* has been removed longitudinally to show the eggs *in situ*. Photographed by the author. × 1½.

The Call Notes. — At 11.30 on the morning of September thirtieth, as the sun became overcast by clouds, I was treated to a pretty serenade by a host of males, which being hidden in a dense thicket of weeds gave out an exquisite example of their orchestration.   Beyond this spot, in the open field planted with clover, but grown over with a mixed wild herbage, which included more or less scattering of the horse-weed, I heard the shrilling.   After a little experience, one is led quite easily into the presence of these crickets by their song, as the following

FIG. 2. — *Œcanthus fasciatus.*   The female is shown on the male's back in the attitude of devouring the plasmatic secretion within the thoracic gland located at the central part of the metanotum in the male.   Photographed by the author, from living posed individuals, which were first subjected to partial asphyxiation with hydrocyanic gas.   × 1½.

incident will prove.   At 2.30 in the afternoon of October first, during the bright warm sunlight, I heard what seemed to be a chorus of *fasciatus* emanating from a source quite a distance off. From the open field where I stood, I gradually traced the trills to a corner of an adjoining unmowed field where the crickets appeared in abundance in a small wild blackberry patch.   On near approach some of the songs ceased, but they soon commenced again when I stood perfectly quiet.

After nightfall, as well as in daytime, the high-pitched shrill notes of this œcanthid are uttered at irregular intervals, sounding not unlike the croaking of a frog or of a sparrow's notes when heard at a distance. They are not so monotonous as those of the large familiar black gryllid, or so resonant as the notes of the mole cricket. The concerts accompanying their little social gatherings may well be placed among the choicest of insect orchestrations.

Method of Alluring the Female during Courtship. — The male of this œcanthid possesses a remarkable mechanism for alluring the female during the period of courtship. He not only uses the pretty modified tegmina as an artifice in attracting her, but he also brings into operation a most peculiar thoracic device about to be described. In order to attract the female, the male, having approached within her sight, commences his advances by elevating his transparent tegmina to a nearly vertical position or right angle. Then separating them so that their surfaces rub together in and out, he produces a high-pitched shrilling for the female's benefit. She, in turn, being readily attracted by these notes moves towards him, and climbing on his back goes sufficiently far forward that her attention is further drawn to the little odd-shaped glandular fossa on the back of the thorax between the wings. Here she at once inserts her mouth to find a delicious potion secreted for her special needs, and which she devours ravenously, as depicted in Figure 2. The male in the meantime may or may not cease his singing, but while she is availing herself of the curious plasmatic drink, his tegmina are continually elevated, and his wings, which are folded at his sides, undergo a slight rhythmical motion in and out, lasting during the five to ten minutes she is usually content to stay. When she moves away he backs around towards her, again elevating his tegmina and repeating his song. Similarly affected by his overtures, and remembering the reward of sweets awaiting her return, she again mounts his body and proceeds to partake from his loving cup. These executions are repeated several times as a preliminary to the sexual act. Now the female is prepared by some subtile influence exerted by the male and she stays near by ready to again answer to his allurements. He

finally raises his tegmina in full display, and singing again to her she immediately reciprocates by mounting his body, but instead of indulging in his loving cup this time, she curves the end of her abdomen slightly downward, while at the same time he backs up and raising the end of the abdomen, conjugation is effected. The latter process lasts but a few seconds. After the sexual act, the female may be seen curving the end of her abdomen underneath forward, in order that she may clean the ovipositor with her mouth and include the genitalia in this toilet.

I have frequently observed the males in active combat over the possession of the female. As a result of these struggles, later on in the season, the males become decidedly dilapidated in appearance, the legs and wings having suffered more or less destruction as the result of the many contests for supremacy.

The Alluring Gland. — The function of the gland (Fig. 3), as above intimated, is solely for the purpose of alluring the female and it may be classed as a secondary sexual organ. It may be described as a moderately deep fossa, situated in the center of the metanotum of the thorax. It is bounded laterally by convex, rather obtusely rounded sides which converge and coalesce in front. Here anteriorly the border is flattened or depressed. On either side before the middle the lateral borders are strongly tumose, being provided with numerous sensitive hairs, the lateral borders behind the middle being continued into narrow convex ridges. The inner margins of the lateral borders are trisinuately excavated. Behind the gland lies the anterior concave border of the scutellum. Within the gland, occupying a point opposite the middle sinuation on either side (Fig. 3, *c*), is a flat brush of glandular hairs which project into the cavity obliquely. Just below, on either side, is another smaller brush (Fig. 3, *b*) composed of similar hairs which are directed inwards. The posterior half of the floor of the cavity is darker in color, being chitinized, and thus showing a line of demarcation separating it from the forward translucent portion. The posterior floor is, moreover, divided by a transverse sinuous ridge, and the inner third here behind (Fig. 3, *d*) is clothed with hairs.

An experiment on live crickets demonstrated that when the hairs on the surface of the swollen anterior lateral borders (Fig.

3, *a*) were stimulated by touching them with the point of a small artist's brush, or head of an insect pin, it gave rise to a responsive movement of the wing of the opposite side of the body. The same stimulus applied to both sides at the same time caused both wings to move or jerk simultaneously.

From these simple experiments I am led to infer that the motions of the wings witnessed during the sexual performances previously described are automatic in nature. They are caused
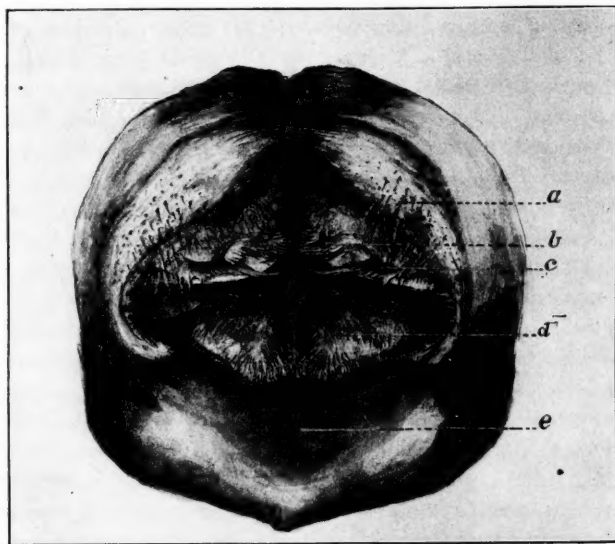

FIG. 3. — Enlarged view of the male alluring organ from above, in the scutum of *Œcanthus fasciatus*. The disposition of the sensitive hairs on the swollen lateral margins anteriorly are shown at *a*, the brush-like arrangement of the glandular hairs *b* and *c*, and the clothing of hairs on the posterior wall at *d*.   Behind the organ or g.and, lies the scutellum *e*. Drawn by the author.   × 15.

by the female palpi touching the sensitive hairs above alluded to, during the time she is drinking.

When examining the male, one may often find, when raising the tegmina, a small plasmatic yellow droplet of the glandular secretion on the under side of the lower tegmina, opposite the position of the gland. This is an excessive fluid secreted from the glandular hairs. The gland fossa is often found filled

with the fluid, which seems to be partially soluble in water. When the gland becomes dried out, the evaporation of moisture causes the hairs, which are normally arranged in the flat rows before mentioned, to come together forming acute pencils. These pencils then take on the appearance of teeth, quite misleading to the casual observer. A small drop of water carefully placed in the cavity, while under the microscope, soon dispels this illusion by causing the hairs to spread out in the same way that a hair brush shows its individual hairs after a dried, sticky substance has been soaked out of it. My illustration (Fig. 3) presents a view of the entire gland after being treated with a drop of water.

From the foregoing statements regarding the sexual habits and the connection of this gland therewith, it may be of interest to note that the suggestion made by Blatchley (*Orthoptera of Indiana*, p. 452), that during the mating of this species the female removes the semen from the glands whose openings are intimated to be beneath the tegmina of the male, and that she then fertilizes her ova with the secretion there obtained is, as a matter of fact, wholly erroneous. There is also a doubt regarding the correctness of certain notes of Harrington on the habits of the snowy tree cricket, which has a bearing on this subject. Howard quotes Harrington as mentioning the following : "An interesting feature of its concerts is one of which I have not been able to find any mention in books accessible. While the male is energetically shuffling together his wings raised almost vertically, the female may be seen with her head applied to the base of the wings, evidently eager to get the full benefit of every note produced." (*Insect Book*, p. 344.) My studies of the thoracic gland of the snowy cricket show this structure to be similar to that of the striped species, *fasciatus* ; consequently, is it not possible that Harrington witnessed the female in the act of drinking from the gland without realizing the entire mission of her attitude ? Blatchley gives an interesting account of the male wooing the female in the work before cited. He found them on the heads of the sunflower.

Besides the alluring gland above referred to, this œcanthid has a singular eversible, sacculated structure situated at the dor-

sum of the abdomen, in the fold between the third and fourth tergites.   In handling the living male, and raising the tegmina with one's fingers to an angle of forty-five degrees or more, the gland may be detected.   It does not protrude except during the first moments of excitement of capture when its folds are thrust out.   This would indicate that the structure is a repugnatorial organ, though this is conjectural, there being no odor given off from it.   A similar gland occurring in a like situation, on the dorsal aspect of the allied snowy cricket, *C. niveus*, gives to the insect, when likewise excited, a faint odor not unlike some flower.

The Method of Oviposition. — On October first, I examined a large number of the horse-weed and golden-rod a-field, which showed the scars where the crickets had oviposited.   The fact was developed that the eggs of this species were always deposited on the sunny south exposure of the main stem of the plants. This is obviously an advantage in furnishing the necessary heat in hatching the eggs, and to the delicate young when they first emerge.   In Figure 1 the serial subfigures represent the stems of the blackberry, horse-weed, and golden-rod, all shorn of leaves, to demonstrate the scars or holes, as well as the eggs *in situ*. I witnessed the act of oviposition for the first time on the afternoon of September 12, and thereafter observed it on a number of occasions.   In brief the process is as follows : the female coming to a suitable spot on the stem, she prepares it by biting it with her jaws, spending scarcely a minute in doing so.   Then, moving her ovipositor under her body at nearly a right angle, she places the tip into this superficial abrasion and immediately proceeds to drill a hole.   The drilling is accomplished by rotating the ovipositor while keeping the end, which is provided with a dentate rasp, firmly pressed against the stem.   The abdomen, which she turns from side to side, takes an active part in this procedure, acting as upon a pivot, and at times covering about forty degrees in these movements.   The ovipositor is soon passed through the tough external covering and finally penetrating deeper and deeper into the pith.   In the beginning the course of the hole takes a right angle, but as she proceeds its direction is changed, taking a curved inclination backwards, as

depicted in Figure 1, *d*. When the female has bored into the pith as far as the ovipositor can go, she then discharges the slightly curved egg very slowly. Then after withdrawing the organ, she finishes the process by chewing the stem at the point of entrance as she did in the beginning of the operation. The anterior, whitish tipped pole of the egg usually lies within a millimeter of the opening. This is shown in the specimen of golden-rod (Fig. 1, *d*) laid open for inspection. Some of the eggs here show the whitish micropilar extremity quite clearly. I did not see the female use the same hole for the deposition of more than one egg.

One night at 7.30, under artificial light, I observed a female boring a hole, but when she arrived at the stage where she was about to oviposit, she suddenly pulled out her ovipositor without having accomplished her purpose. It was then disclosed that the egg had stuck in its passage, for the next moment she brought the ovipositor forward underneath her abdomen and, spreading the blades apart, she extracted the egg with her mouth and rapidly ate it. This latter act does not seem to be unusual among the orthoptera under like conditions, as I have witnessed it in several widely different species. She then went over her ovipositor carefully cleaning it with her mouth. Commencing at the tip, she spent several minutes passing from the point along its entire length, giving great attention to the preparation of the base and genitalia. This latter performance seemed to have been done with a view to forestall further accidents, for almost immediately afterwards she started to again oviposit, and this time, as well as thereafter, had no difficulty in placing her eggs successfully.
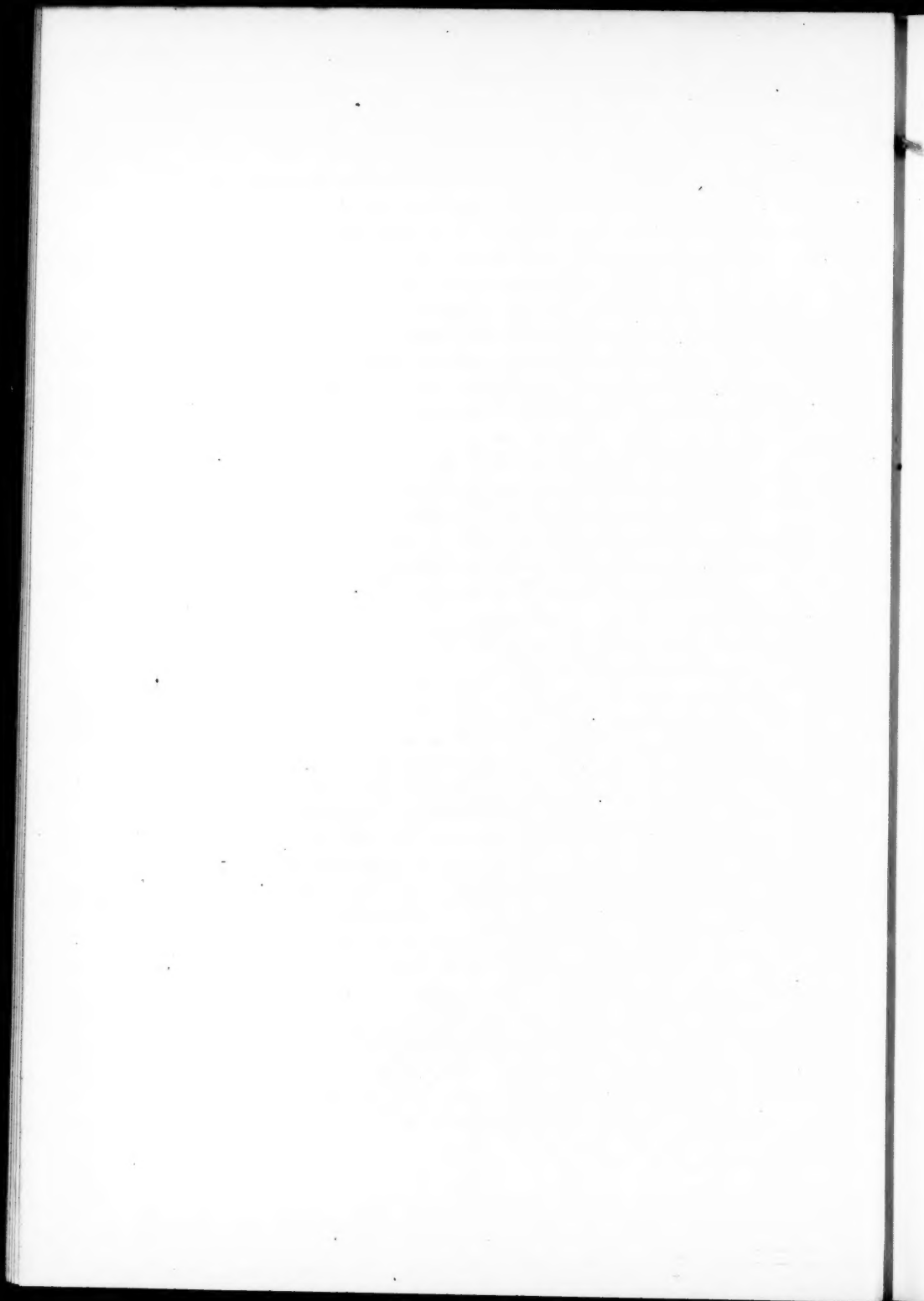
THE EMBRYO OF THE ANGIOSPERMS.

HAROLD L. LYON.

THE angiosperms are the dominant plants of present floras, and were the first to be thoroughly studied by botanists. The seed habit, providing a definite period for embryonic development, and the large embryos, often obtaining as a result, made the embryology of the angiosperms especially easy and attractive. Simple lenses and primitive technique served for the study of these embryos, and a knowledge of them was well advanced before better instruments and better methods were employed to elucidate the embryogeny of lower forms.

The angiospermous embryo was early hit upon as furnishing fundamental data for systematic classification. This quickly brought such embryos into prominence in botanical literature, and controversies immediately arose as to the morphological values and homologies of the embryonic members. While a creed, serviceable and satisfactory to the systematists, was soon evolved, the chief questions in morphology have continued to the present day quite unanswered. The aspect of the problem has changed from time to time with increasing knowledge and if we would now attempt a solution we must strive to answer the three following questions.

Are the angiosperms monophyletic?

Are cotyledons true leaves?

To what structure, if any, in the monocotylous embryo are the cotyledons of a dicotylous embryo equivalent?

An answer to the last question is, of course, the one most generally desired; but to discuss this question one must take some position as to the phylogeny of the classes of angiosperms and to the morphological value of cotyledons.

ARE THE ANGIOSPERMS MONOPHYLETIC?

It had been so generally conceded that the angiosperms have a common ancestry that in a former paper the writer (: 02) dis-

missed this question with the following brief statement, "That
the Monocotyledons and Dicotyledons have a common ancestry
there is no reason to doubt. One would hardly suppose that
the similar complicated cytological phenomena of embryo-sac
development and endosperm formation were simply parallelisms
in two groups of different phylogenetic origin." Later, how-
ever, Balfour (:01) in discussing the phylogeny of the angio-
sperms, said, "Were I to maintain an opinion it would be that
the two classes have arisen on separate lines of descent. The
embryo characters as well as those of the epicotyl can, I think,
be shown to be fundamentally different and to afford no basis
for an assumed phyletic connection."

Since Balfour, Coulter and Chamberlain (:03) have written
on the same subject as follows : " The first phase of the prob-
lem has to do with the common or independent origin of the
Monocotyledons and Dicotyledons. It has been assumed gen-
erally that the two groups are monophyletic. The chief argu-
ment, and in fact the only morphological one for the monophyletic
theory, lies in the great uniformity of the peculiar development
of both male and female gametophytes. It is argued that the
independent origin of such exact details of development and
structure is inconceivable, and this argument has been reën-
forced recently by the discovery in both groups of the peculiar
phenomenon called 'double fertilization.' The argument is cer-
tainly a very strong one, and yet there are rebutting proposi-
tions. Even such similarity in structure may be the natural
outcome of the changes that resulted in the evolution of seeds,
and these are now generally believed to have appeared in inde-
pendent lines. Again, the fundamental differences in the devel-
opment of the embryos of the two groups are hard to reconcile
upon the theory of monophyletic origin. Add to this the funda-
mental differences in the structure of the stem and in the
character of its vascular bundles, and the derivation of one group
from the other seems more inconceivable than the derivation of
the Dicotyledons from the Gymnosperms. Still another argu-
ment against the monophyletic theory is furnished by the histori-
cal testimony. The Proangiosperms of the Lower Cretaceous,
so far as known, appeared associated with undoubted Mono-

cotyledons, and merged gradually into recognizable Dicotyledons. The emerging of Dicotyledons from this vague group either indicates that Monocotyledons and Dicotyledons originated independently, or that the Proangiosperms were transition forms between Monocotyledons and Dicotyledons. This latter alternative is in turn inconceivable, especially since the most primitive Dicotyledons are recognized to be even more primitive than any of the Monocotyledons..... In our judgment the evidence is strongly in favor of the independent origin of the two groups, which have attained practically the same advancement in the essential morphological structures, but are very diverse in their more superficial features. Their great distinctness now indicates either that they were always distinct or that they originated from forms that were really Proangiosperms and neither Monocotyledons nor Dicotyledons."

Few morphologists will agree with the statement that the only morphological argument in favor of the monophyletic theory is to be derived from the similarity in embryo and endosperm development. There is in both classes a remarkable conformity to one common plan in all phases of their organogeny ; not only in the embryo-sac, but in the development of floral structures, andrœcia, gynœcia, ovules, seeds and fruits. While many similarities in plant structures have undoubtedly resulted through parallel development, is it not carrying the idea to an unwarranted extreme when it is attempted to explain all the exact details of development, which obtain alike in both classes of Angiosperms, as simply parallelisms, especially since no tangible evidence is brought forward to justify it ?

If the fundamental differences in embryogeny are to be delineated by the exceptionally perfected embryos of Alisma and Bursa, as is so generally stated, they might be considered hard to reconcile. If on the other hand they are to be determined by a comprehensive comparison of the various types of embryos to be found in the two classes, the real difficulty is not, how to reconcile these differences, but how to locate them. An examination of recent embryological work [1] will show that no *funda-*

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[1] Sterckx ('99), Lyon (: 01), Cook (: 02), Schmid (: 02), Sargant (: 02, : 03, : 04), Schaffner (: 04), York (: 04).

mental differences can be distinguished.   Coulter and Chamberlain themselves in a previous chapter of the same work, write, "The distinction between Monocotyledons and Dicotyledons is not always clear in the embryo."

Should fundamental differences in the structure of the stem and its vascular bundles be pointed out, this "*rebutting proposition*" might prove a serious one.   It is certain, however, that such an opinion can carry little weight when opposed to the conclusions of careful investigators supported by their researches. And almost without an exception, students [1] who have actually worked on the stem anatomy of the angiosperms with a view to determining their phylogeny, concur in the opinion that here also the evidence is for and not against a monophyletic origin. There is a characteristic type of stem and bundle structure prevalent in each class it is true, but in certain plants of both they so closely approximate a common type that no hard and fast line can be drawn between the classes on this basis.   That both types have been evolved within the angiosperms from one fundamental pattern is amply demonstrated by existing plants as the above mentioned students have shown.   Coulter and Chamberlain (: 03) would place the Nymphæaceæ among the dicotyledons because of their embryo-characters ; but no one has ever been able to show that the stem structure of the Nymphæaceæ is other than essentially that characteristic of monocotyledons.   In placing the Nymphæaceæ as they do, they themselves admit that there are no differences in stem structure between the plants of the two classes which are fundamental.

As to the historical testimony which is to be derived from palæobotany, Seward (: 03) has shown that, in the extent of our present knowledge, it is to be considered of questionable value.

While giving due consideration to these adverse opinions ; admitting that an independent origin of the monocotyledons and dicotyledons is not inconceivable, and that all their common morphological, structural and cytological peculiarities might be simply parallelisms ; still we are justified in accepting the strongly fortified conclusion, borne out by all obtainable evi-

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[1] Queva ('99), Jeffrey (: 00, : 03), Worsdell (: 02), Sargant (: 03).

dence, that the angiosperms are monophyletic ; that their most recent common ancestors were Angiosperms.

ARE COTYLEDONS TRUE LEAVES ?·

The oldest and at all times the favorite interpretation of cotyledons is that they are arrested or metamorphosed foliage leaves. The antiquity of this view as well as the basis on which it was founded is well set forth in the following quotation from Sachs' *History of Botany*.[1] "We see that Cesalpino uses the same word ' folium ' without distinction for calyx, corolla and ordinary leaves ; just as he and Malpighi a hundred years later unhesitatingly regarded the cotyledons as metamorphosed leaves. In fact the envelopes of the flower and the cotyledons approach so nearly to the character of leaves that every unprejudiced eye must instinctively perceive the resemblance."

From time to time various authors, while accepting the foliar theory of cotyledons in its general application, have concluded that the analogous structures in certain plants are not true cotyledons but organs of a different morphological value. The scutellum of the grasses, which is now commonly considered a cotyledon, has been variously interpreted.[2] Richard ('11) distinguished as ' Embryons macropodes ' the embryos of the grasses, Nelumbo, Ruppia, Hydrocharis and Zostera. The scutellum of the grass embryo and the cotyledonary lobes of the embryo of Nelumbo he considered homologous to the massive, macropodous portions (l'hypoblaste) of the embryos of Ruppia, Zostera and Hydrocharis. This hypoblast he interpreted as a lateral outgrowth or expansion of the radicle. Schaffner (:04) compares the embryos of the Nymphæaceæ with those of Ruppia, Zostera and Halophila. He reiterates Richards conclusions concerning the homology of the cotyledonary lobes with the macropodous body which he terms a hypocotyledonary expansion.

Nageli ('78), however, early ventured the opinion that " Der Embryo der Gefässkryptogamen und der Phanerogamen ist kein Caulom sondern ein Thallom, wie das Moossporangium, aus dem

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[1] English translation 1890, p. 48.
[2] *Vide* Bruns ('92) and Kennedy (:00).

er phylogenetisch hervorgegangen ist; die Samenlappen sind keine Phyllome, sondern Thallomlappen. An dem Embryo tritt als neue Bildung der Stengel auf."

In a lecture delivered at the Minnesota Seaside Station in June, 1901, and since published in the Year Book of the station, the writer suggested that cotyledons are not arrested leaves but are primarily haustorial organs, originating phylogenetically as the nursing-foot in the Bryophyta and persisting throughout the higher plants.

Balfour, in his presidential address to the Botanical section of the British Association, September meeting, 1901, said, "We ought, I think, to look upon the embryo of the angiosperms as a protocorm of embryonic tissue adapted to a seed life. Under the influence of its heterotropic nutrition and seed environment it may develop organs not represented in the adult plant, as we see in, for instance, the embryonal intra-ovular and extra-ovular haustoria it often possesses. There is no reason to assume that there must be homologies between the protocorm and the adult outside an axial part with its polarity. There may be homologous organs. But neither in ontogeny nor in phylogeny is there sufficient evidence to show that the parts of the embryo are a reduction of those of the adult. . . . . I cannot pursue the subject here nor discuss the view of the cotyledons as either ancestral leaf-forms or arrested epicotylar leaves. The analogies with existing Pteridophytes that are cited are not pertinent, for there is no evidence that angiosperms have that ancestry, or indeed that their phylogeny was through forms with free embryos. Nor is the fact of resemblance between cotyledons and epicotylar leaves and the existence of transitions between them convincing. That the cotyledons, primarily suctorial organs, should change their function and become leaf-like under the new conditions after germination is no more peculiar than that the hypocotyl should take the form of an epicotylar internode from which it is intrinsically different as the frequent development upon it of hypocotylar buds throughout its extent shows."

While each of the above authors expresses a distinct interpretation quite at variance with those offered by the others, still all declare alike on our present point of discussion, that cotyledons are not morphologically foliage-leaves.

Ramaley (: 02), who for the past ten years has been working on the comparative anatomy of dicotyledonous seedlings, expresses his opinion on this subject in the following statement: "I think also that the theory of the above named writer [Preston, : 02] to account for the lobing of cotyledons is of no great value. He suggests that the lobing of the foliage leaf is 'thrown back' upon the cotyledon. This assumes firstly that 'throwing back' can actually occur, while as a matter of fact it yet remains to be proven; and secondly, that the cotyledons are homologous with leaves, something which also remains unproven. The suggestion[1] concerning the morphology of the cotyledon made at the recent Chicago meeting of botanists of the central states seems more reasonable than the one which would consider the cotyledons as really a leaf."

Many other writers have expressed dissatisfaction with the foliar theory without taking a decided stand against it. Klebs ('83) in his excellent treatise on germination pronounces the subject an enigma, while Lubbock ('92), who has undoubtedly made more extensive observations upon seedlings than any other one man, writes: " No one who has ever looked at young plants can have failed to be struck by the contrast they afford to the older specimens belonging to the same species. This arises partly from differences in the leaves, partly from the contrast which the cotyledons, or seed-leaves, afford, not only to the final leaves, but even to those by which they are immediately followed. This contrast between the cotyledons and true leaves is so great that one might almost be pardoned for asking whether they can be brought in correlation. So far, indeed, are the cotyledons from agreeing with the forms of the leaves, that the difficulty is to find any which have been clearly influenced by them. One species of Ipomœa (I. Pes-capræ) has both cotyledons and leaves, as the name denotes, somewhat like the foot of a goat; but the leaves vary considerably, and it is probable that the resemblance may be accidental. A clear case is, however, afforded by the Onagrarieæ, where in Œnothera and some allied genera the form of the mature cotyledons is

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[1] Lyon (: 02).

evidently related to the leaves.   Even here, however, the resem-
blance is confined to a basal portion of the cotyledon which
makes its appearance subsequent to germination, and no trace
of it is shown in the cotyledons themselves when they first
appear."

We can readily see from Lubbock's work that a morphological
leaf-value has been ascribed to cotyledons solely on their resem-
blance to foliage leaves, a resemblance which is acquired after
germination when the cotyledons are functioning as photosyn-
thetic areas.   Then they are only in general leaf-like, for if any
cotyledons be compared with the foliage leaves of the same
plant they are found to differ from these, usually to a marked
degree in form, texture and venation.   The resemblance is never
more than such as might be wholly induced by the assumption
of the vegetative function, for the cotyledons become function-
ally similar structures in the same environment as the leaves.
Natural forces seem to call forth a remarkably constant type of
foliar organ in all those plants where any extent of tissue is
specialized for this purpose no matter what the morphological
value of the tissue may be.   The gametophytes of some mosses
develop leaves which are quite similar to the simpler leaves
produced by the sporophytes of many pteridophytes and phan-
erogams.   Phyllodes and Phylloclades are well known cases
where the assumption of the function has, in many instances,
been followed by the assumption of the form of leaves.

Ramaley has undertaken a study of the comparative anat-
omy of cotyledons and leaves.   In his paper (:03) on the coty-
ledons and leaves of the Papilionaceæ, he writes: "In the
plants examined, all of which have cotyledons which function
for a time as leaves, the anatomical structure is strikingly differ-
ent in cotyledons and leaves. . . . . The stalk of the cotyledon
when present has a structure different from that of the leaf-
stalk."   Again (:04) he writes: "In the Ranunculaceæ and
Cruciferæ studied there is not as great a difference in structure
between cotyledons and leaves as was seen in the Papilionaceæ.
. . . . The stalks of the cotyledon and leaf are quite different in
anatomical structure. . . . . In these families as in the Papilionaceæ
there seems to be no relation in external form between the coty-
ledon and leaf."

The ontogenetic origin of the cotyledons ·would seem to deny the foliar theory since they do not arise as exogenous lateral outgrowths upon the growing point of the stem as do all later foliar structures.   Their appearance always precedes the differentiation of the stem-apex.

Thus it appears that the foliar theory is supported only by the fact that in some plants the cotyledons are borne on a stem and are green, and may acquire a form resembling a leaf.   It seems certain that any " unprejudiced " observer must at once admit that these are but superficial analogies ; quite insufficient evidence to warrant the conclusions so universally based upon them.

To what Structure, if any, in the Monocotylous Embryo are the Cotyledons of a Dicotylous Embryo Equivalent?

Early embryologists considered the cotyledons of all angiosperms (with the exceptions already noted) to be structures of the same category, morphologically as well as physiologically, and their conclusions have been accepted by botanists in general.

Balfour (: 01), however, states that, " This terminal cotyledon in the Monocotyledons is not a leaf nor the homologue of the lateral cotyledons in the Dicotyledons."

In this opinion he is again supported by Coulter and Chamberlain (: 03) : " The current opinion regards it [the cotyledon] as a modified foliage leaf, and this is borne out in the majority of Dicotyledons by the assumption of the foliage function.   The terminal cotyledon of Monocotyledons, however, seems to belong to a different category, and to hold no relation to a foliage leaf or to a foliar member of any description."   To discover evidence which will in general prove the homology of the cotyledons, one has but to consult the recent works of Sterckx ('99), Lyon (: 01), Cook (: 02), Schmid (: 02), Sargant (: 02, : 03, : 04), Schaffner (: 04) and York (: 04).   Just as the observations of the above mentioned investigators dispel all idea of such fundamental differences in the embryos as would indicate two types of different phylogenetic origin, so also do they show clearly that the coty-

ledons of the angiosperms are morphologically of one category.
In 1809 Poiteau published the theory that the epiblast of cer-
tain grasses represents a vestigial cotyledon thus indicating a
dicotyledonous origin for these plants.   This hypothesis has won
many adherents and but recently Van Tieghem ('98) has, on the
strength of it, placed the Grasses with the Nymphæaceæ under
a third class of angiosperms which he calls Liorhiza dicotyledons.
Van Tieghem's classification has been adequately dealt with by
Balfour (: 01, : 02) and needs no further attention from us at
this time.   Poiteau's idea of the reduction of one cotyledon was
employed by Henslow ('93) to explain the origin of the mono-
cotylous condition throughout the Monocotyledons.

Agardh ('29–'32) also accepted Poiteau's interpretation of the
grass-embryo but considered the Gramineæ the only true mono-
cotyledons.   The Naiadeæ, Palmæ, Aroideæ, Lilieæ and Scita-
mineæ, and probably other families of monocotyledons, he
classed as syncotyledones, considering the terminal structure of
their embryos to represent two cotyledons which had become
fused into a single member.

In a previous paper, the writer (: 02) also concluded that the
cotyledon of a monocotyledon was equivalent to both of the coty-
ledons of a dicotyledon, but that the monocotylous condition
was the more primitive and that from this the dicotylous condi-
tion had arisen through a bifurcation of the originally single
cotyledon.   The morphological value ascribed to the cotyledon
led primarily to this conclusion which was further strengthened
by embryological studies in the Nymphæaceæ.

In a series of admirable papers, Miss Sargant (: 02, : 03, : 04)
has brought together much evidence, of which her own research
work has furnished a very important part, showing that the
cotyledon of a monocotylous embryo is equivalent to both of the
cotyledons of the dicotylous embryo.   Add to this the evidence
from the Nymphæaceæ embodied in the recent works of Lyon
(: 01), Cook (: 02), Schaffner (: 04), and York (: 04) and the con-
clusion would seem a necessity.   In considering the phylogeny
of the angiosperms, however, Miss Sargant has accepted the
view suggested by Agardh, that the monocotylous condition has
been derived from the dicotylous condition through the fusion of

two cotyledons into a single member. Thus while the relative value of the cotyledons in the two classes needs no further discussion at this time, we have yet to choose between the hypothesis elaborated by Miss Sargant and the one suggested by the writer.

It is obvious that the anatomical and morphological evidence collected by Miss Sargant can as readily be interpreted in support of the writer's hypothesis as the one brought forward by herself. It can quite as well be interpreted as showing a transition from the monocotylous to the dicotylous condition by a bifurcation of the cotyledon, as demonstrating a reduction from the dicotylous to the monocotylous condition through a fusion of two cotyledons. It can be read forward as well as backward. Progression in evolution is quite as plausible as retrogression, yet Miss Sargant hopes to convince her readers with the following unique argument : "To conceive of steps by which two separate cotyledons should gradually unite is easier than to imagine a single cotyledon splitting into two similar members as suggested by Mr. H. L. Lyon."

While Miss Sargant is able to cite some thirty dicotyledonous seedlings as having their cotyledons partially or completely united into a single member, one might easily mention a hundred dicotyledonous seedlings having their cotyledons deeply emarginate, bifid or even bipartite. Then cotyledons deeply three-lobed, four-lobed, and five-lobed are not unknown. In various species of Acer, seedlings with three and four distinct cotyledons are of frequent occurrence. *Pittosporum crassifolium* produces three or four cotyledons quite as often as two, while *Nuytsia floribunda* habitually produces embryos with three or four cotyledons. Would the writer propound an inconceivable hypothesis were he to suggest that in these dicotyledons the variously lobed and polycotyledonous conditions had arisen through a splitting of cotyledons ; or must he adopt that "easier" line of reasoning and maintain that the polycotyledonous condition is the more primitive, and that the dicotyledonous condition has been arrived at through a reduction by the gradual union of the many members into two ? All morphologists will affirm that this lobing of the cotyledons has resulted through adaptation to the various

conditions imposed by the seeds.   Might not these same causes, whose effect on two cotyledons is so often apparent, have primarily induced the division of a single cotyledon into two?   In considering divided cotyledons, Lubbock ('92), concludes that the bifurcation of the cotyledons in such plants as Eschscholtzia and Schizopetalon are adaptations whereby the cotyledons are better able to free themselves from the seed.   If for this purpose four cotyledons are superior to two, in what far greater proportion are two cotyledons superior to one?

Although its evidence can never be taken as absolute, still we are justified in placing some value on recapitulatory development. If the monocotylous condition arose through the union of two cotyledons we might reasonably expect to find, in our transition-types, that two distinct cotyledon-primordia would first appear, and conjoint development occur later.   Such a sequence we actually find in the development of gamophyllous perianths. But in all the anomalous forms cited by Miss Sargant, of which the embryogeny has been studied, a single primordium first appears which, if the cotyledon is to become lobed at all, later bifurcates.

In her first paper on this subject, Miss Sargant (:02) attributed the reduction of the cotyledons to their specialization as a sucking organ.   Of the monocotyledons, she writes, " I have regarded them for some time as specialized forms of an ancestor with two seed-leaves.   The complete union of the cotyledons may very possibly be due to their common specilization as a sucking organ.   It is true that all cotyledons begin life by absorbing nourishment from a food-body within the seed, but in dicotyledonous seedlings they commonly lay aside that function at an early period, even though they may never become assimilating organs.   Among Monocotyledons on the contrary, the apex of the cotyledon often remains within the endosperm throughout the existence of both, a period which covers years in palms and some other plants.   Such a habit as this would naturally lead in course of time to the fusion of the cotyledons within the seed."   This hypothesis would seem to maintain that the specialization in seeds has been from the exalbuminous towards the albuminous condition.   This supposition however meets

with immediate denial from our knowledge of the phylogeny of seeds.

In her later papers, Miss Sargant (: 03, : 04) fails to reiterate the above hypothesis of the reduction factor but says : " These considerations have led me to look upon the Monocotyledon as an organism adapted primarily to a geophilous habit," and " Suppose a race of primitive Angiosperms to be specialized as geophytes. Their originally distinct cotyledons become more and more closely united in order to economize material. In the end a single cotyledonary member is formed by their complete fusion. A monocotyledonous race might easily be derived in this way from one with two cotyledons." While it is possibly true that the development of cotyledonary tubes has resulted in some dicotyledons through adaptation to a geophilous habit ; just how this habit might have caused a fusion and subsequent reduction of the blades of the cotyledons, Miss Sargant does not make clear in any of her papers ; and how the habit should finally force the cotyledon into the subterranean position char- acteristic of monocotyledons receives no explanation at all. Furthermore, her hypothesis would seem to require that the primitive angiosperms were not geophytes. It is now commonly held that the angiosperms are the progeny of pteridophytic ancestors, and it might be well to consider that the geophilous habit is quite prevalent among the Pteridophyta.

Finally, the entire structure of Miss Sargant's theory is built upon the assumption that cotyledons are morphologically foliage- leaves. But we have already found that this assumption is dis- proved by our knowledge of the form, structure, and develop- ment of cotyledons. To make her theory seem tenable, Miss Sargant must first make plausible this assumed premise on which the validity of her hypothesis so largely depends.

RECAPITULATION.

The great value ascribed to the embryo in the systematic classification of the Angiosperms early brought such embryos into prominence in botanical literature. Thus we find that angiospermic embryology embodied an extensive knowledge

before any careful work had been done on the cryptogams. As a result an interpretation of the angiospermic embryo was evolved wholly from evidence obtained from angiosperms and without reference to any evidence which cryptogamic embryos might furnish. This interpretation in the hands of the systematists soon became a fixed creed which has come down to the present day as built upon facts too well established to be questioned. Some morphologists have, it is true, attacked this creed, but have failed to lessen in the slightest degree its general acceptance.

Because the cotyledons of certain plants assumed the function and approximated the form of leaves, a morphological leaf-value was, from the first, ascribed to them. This hypothesis, framed on simple analogy, is the self-evident fact which constitutes the basis for all later acceptable embryological considerations. If cotyledons are morphologically foliage leaves, that the most primitive angiosperms must be those of which the cotyledons most nearly approach foliage leaves, is a conclusion which naturally followed. And hence the creed recognized the dicotyledons as the most primitive and considered the monocotyledons a race derived from them. Some theorists would derive the monocotylous condition from the dicotylous, by the abortion of one cotyledon, and others, through the fusion of the two cotyledons into a single member.

Following, and followed by others, the writer has concluded that cotyledons are not metamorphosed foliage leaves. The writer has further suggested that they are primarily haustorial organs originating phylogenetically as the nursing-foot of the Bryophytes and persisting throughout the higher plants; that the monocotylous condition is the more primitive and that the dicotylous condition has arisen through a bifurcation of an originally single cotyledon.

There are, it is true, certain dicotyledons which show a tendency to reduce one cotyledon and others in which a partial or complete fusion of the cotyledon petioles undoubtedly takes place, yet there is no evidence to justify the sweeping application of either process in explaining the origin of the monocotylous condition.

The embryos of the so-called anomalous dicotyledons can as readily be interpreted as demonstrating the bifurcation of one cotyledon as proving the fusion of two, and if we take into account the course of events in their ontogeny they support the former hypothesis in preference to the latter.

While, as mentioned above, some few dicotyledons show a tendency to reduce the cotyledons there is an opposite tendency far more prevalent among dicotyledons to produce lobed, bifid and bipartite cotyledons ; undeniably a process of splitting.

Finally if the foliar-theory of cotyledons can be established the writer's entire hypothesis must fall. If the adverse hypotheses are to be proven, the foliar-theory must first be established.

THE PHYLOGENY OF THE COTYLEDON.

In a paper now in preparation, the writer will endeavor to demonstrate the validity of his hypothesis concerning the phylogeny of the cotyledon. A previous paper (:02) on this subject only served to indicate in an indefinite way the scope of the theory. Since that time continued investigations in the field, laboratory and library have yielded evidence which bears out to a remarkable degree the fundamental idea, at the same time furnishing the necessary details for a more exact formulation of the hypothesis. The following outline illustrates the application of this hypothesis to plant embryology.

Cryptogamic embryos. — The first regional differentiation of the body-tissue of the sporophyte was into the spore-containing capsule and the bulbous nursing-foot; the function of the former being the bearing and protection of the spores, that of the latter the absorption of nourishment and the furnishing of mechanical support. Since these two regions form the bases for all later elaboration of the sporophyte we may conveniently assign to them the distinctive names of *sporophore* and *haustrum*. As the haustrum and sporophore are not always distinguishable from the first in the embryo we will find the term *protocorm*[1] quite ser-

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viceable as designating the whole embryo before this primary
differentiation is complete, and the term *metacorm* for the plant
body after the differentiation of its permanent members.   All
of the protocorm or only a portion of its tissue may be employed
in the formation of the metacormal primordia.

In the Bryophyta the haustrum remains embedded in the tis-
sue of the gametophyte throughout its own existence, but in the
Pteridophyta it acquires the habit of anchoring the sporophyte
in the soil after the tissue of the gametophyte is exhausted.
This seems to have at first resulted in the production of a large,
bulbous haustrum (Phylloglossum, *Lycopodium cernuum*) but
later some haustral tissue became modified into a distinctive
earth-boring organ, the root, a structure much better adapted
for penetrating and drawing water from the soil.   In *Lycopo-
dium cernuum* the bulbous haustrum may give rise to roots,
which in turn may be converted back into bulbous haustra.
While some lycopods produce large, bulbous, geophilous
haustra, among the pteridophytes, as a rule, a bulbous haustrum
is employed only in connection with the gametophyte, the haus-
tral tissue which penetrates the soil being differentiated into a
root.   Thus the primary bulbous haustrum of the bryophytes
becomes differentiated in the pteridophytes into two distinct
haustral organs; the nursing-foot or cotyledon — the haustrum
of the protocorm, and the root — the haustrum of the metacorm.

The capsular sporophore of the Bryophyta gives place in the
Pteridophyta to an axis bearing sporophylls.   Because of their
position, the photosynthetic work falls upon the sporophylls,
and this very soon leads to a division of labor with a consequent
sterilization of some sporophylls as foliage leaves or euphylls.
While phylogenetically the sporophore precedes the haustrum,
the requirements of the former during its development upon the
latter, seems to have stimulated an ontogenetic acceleration of
the haustrum and a corresponding retardation of the sporophore,
so that in ontogeny a functional haustrum precedes the sporo-
phore.   Thus in the embryogeny of Anthoceros and Sphagnum
we find that of the massive protocorms first developed the
greater portion is haustral tissue on which the sporophore stands
as a papilla.   Among the pteridophytes the ontogenetic acceler-

ation of the haustrum is always apparent so that their protocorms are essentially haustral structures from which the sporophore sooner or later develops as an outgrowth.   In Phylloglossum the ontogenetic acceleration of the haustrum is most pronounced, a large bulbous protocorm resulting, from which the sporophore is differentiated at a quite late period (Fig. 2).   As the protocorm of this plant becomes geophilous, it develops leaf-like lobes of tissue which carry on photosynthetic work.   Bower ('94) terms these protocormal leaves, *protophylls,* to distinguish them from the leaves of the metacorm, the euphylls.   With the specialization of the root as the earth-boring haustrum and the euphylls as the photosynthetic areas, the geophilous protocorm with its protophylls disappears from the ontogeny of the higher pteridophytes as we have already found.   Perhaps, however, the first leaf of some of these should be interpreted as a protophyll rather than a euphyll.

In the embryogeny of Lycopodium and Selaginella an outgrowth from the protocorm serves to carry the embryo down into the tissue of the gametophyte.   This protocormal organ, the suspensor, is limited to the lycopods among the pteridophytes but is of general occurrence in the embryogeny of the angiosperms.

The positional relation which the metacorm bears to the protocorm is remarkably different in different cryptogamic embryos. In the Bryophyta the axis of the metacorm is coincident with the axis of the protocorm, the haustrum of the latter developing into the haustrum of the mature plant.   With the advent of the root as the haustral organ of the metacorm, the position in which it is differentiated in relation to the sporophore determines the primary axis of the metacorm.   In some embryos the root is differentiated out of the body of the protocormal haustrum, while in others it appears as an outgrowth from this structure. In *Botrychium obliquum* and Equisetum, the root appears diametrically opposite the sporophore and hence the metacormal axis transfixes the protocorm, the tissue of the latter becoming a permanent part of the metacorm.   In Selaginella, the metacormal axis is differentiated through the tissue of the protocorm, the suspensor being on one side of the axis, and the cotyledon on the

other (Fig. 3).   In the leptosporangiate ferns, the sporophore
and root appear as adjacent outgrowths from the protocorm thus
leaving the haustrum of the latter as a lateral cotyledon on one
side of the metacormal axis (Fig. 4).

Angiospermic embryos.— In the embryogeny of an angiosperm,
a more or less massive protocorm is developed which may, or
may not employ a suspensor.   The form of the protocorm varies
greatly, depending upon the shape and size of the seed, the extent
and vigor of the endosperm, the duration of intraseminal devel-
opment and the many other peculiar conditions presented by the
seed habit.   The sporophore arises as an outgrowth from the
protocorm and its intraseminal development is, as a rule, quite
restricted.   The metacormal axis is always differentiated through
protocormal tissue.   (Figs. 5, 6, and 7.)

In the monocotyledons, the sporophore primordium usually
appears as a distinctly lateral outgrowth from the protocorm :
but with the establishment of the metacormal axis between the
sporophore and root the remaining protocormal tissue stands in
a lateral position to this axis and, as a lateral cotyledon on one
side of this axis, it functions during germination.   As the spo-
rophore primordium of a monocotyledon differentiates into the
plumule the adjacent protocormal tissue grows forward around
it, often completely enclosing it.

In the dicotyledons, the protocorm early bifurcates and the
sporophore primordium arises as an outgrowth between these
two cotyledons which closely invest it during intraseminal growth
(Fig. 7).   In many dicotyledons, a new structure, the hypocotyl,
appears in the morphogenesis of the metacorm.   The hypocotyl
is differentiated between the root and sporophore from tissue
which is phylogenetically haustral.   During germination it serves
to elevate the cotyledons and plumule.   The cotyledons upon
becoming exposed to the light usually become green and often
function for a considerable time as photosynthetic areas.   The
assumption of the function of foliage leaves leads to the assump-
tion of the form of such leaves, and the cotyledons of some
plants approximate to a remarkable degree the form of the later
euphylls.

Gymnospermic embryos. — That the gymnosperms in the ear-

lier stages of their embryogeny show a great diversity has been
known for a long time.   That this diversity is but the more or
less restricted following of one general plan has been pointed
out by Coulter and Chamberlain (: 03²).   Up to the present time
the knowledge of the later stages of their embryogeny has been
quite insufficient for determining the morphological values of
the embryonic structures.   Recent investigation, however, has
served to elucidate some of the obscure points, and the interpre-
tation that would now be offered is as follows.

In Ginkgo a large spherical protocorm is developed in the
venter of the archegonium.   The blastema (metacormal bud)
arises as an outgrowth from the deepest seated portion of the
protocorm and invades the tissue of the gametophyte by its own
growth.   The stem and root primordia are both differentiated
entirely beyond the bulbous protocorm, the axis of the three
members being along one straight line (Fig. 8).   Upon germi-
nation, the protocorm is the first member to be forced out of
the seed and it is followed first by the root and then by the
stem.   Thus the protocormal haustrum, because of its position,
cannot be employed by the metacorm during germination as a
functioning cotyledon.   If any structure is to remain in contact
with the tissue of the gametophyte, it devolves upon the append-
ages of the stem, and in Ginkgo we find the first two or three
euphylls functioning as absorbing organs or pseudocotyledous.

Ginkgo undoubtedly shows, in its embryogeny, the most primi-
tive condition of any of the gymnosperms, for it certainly shows
the least specialization.   In Cycas (Fig. 9) a less perfect proto-
corm is developed and in Zamia (Fig. 10) a further reduction of
its bulk obtains.   In fact it would seem that because of the
positional relation of the blastema to the protocorm the latter
cannot be made use of by the germinating embryo, and its dis-
use leads to an increasing limitation of the structure in gymno-
spermous embryogeny.

In the cycads, protocormal tissue directly behind the blastema,
by rapid growth, carries the metacormal bud down into the tis-
sue of the gametophyte (Figs. 9 and 10).   This structure, the
suspensor, becomes an organ of importance and is retained by all
of the Coniferales.   Their protocorms, however, consist of little

more than a suspensor at the tip of which the metacormal primordia are differentiated (Fig. 11).

The suspensor of a gymnosperm embryo is clearly not homologous to that of a lycopod or angiosperm embryo. In the gymnosperms, the suspensor is developed between the body of the protocorm and the blastema and by its elongation serves to separate these two structures. In the lycopods and angiosperms, it is an outgrowth from the protocorm and has one free end. In these embryos the metacormal axis is differentiated through the body of the protocorm.

Polyembryony sometimes occurs in both gymnosperms and angiosperms through the production of two or more blastemata by one protocorm.

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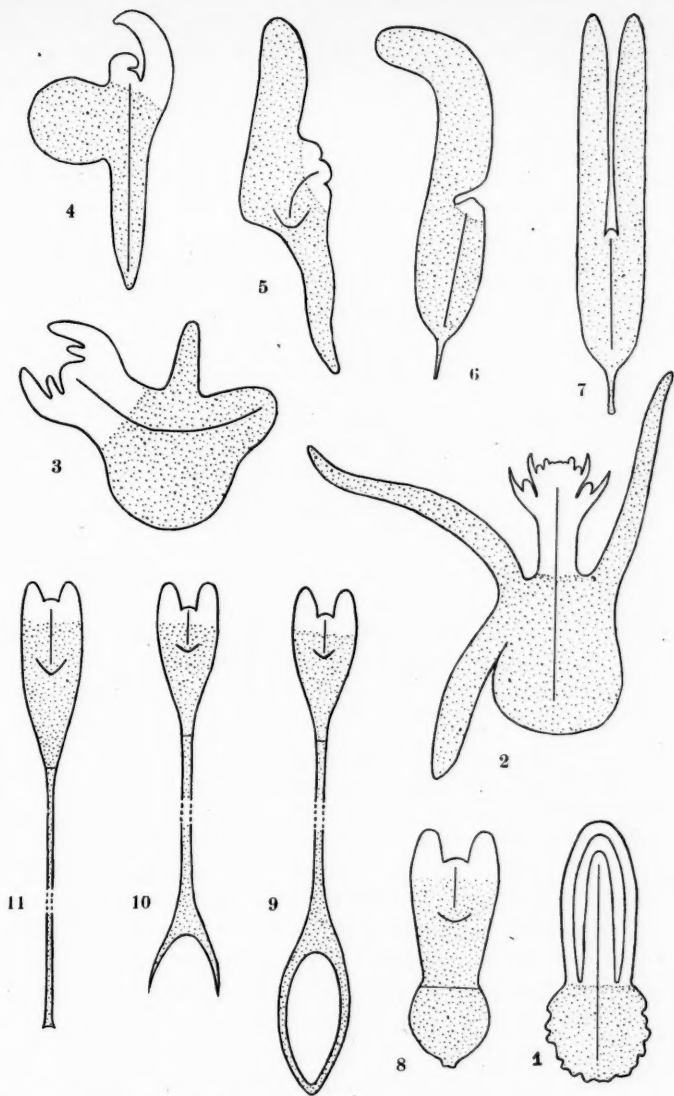   du Jard. Bot de Buitenzorg, 8, 23–34.
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The accompanying diagrams serve to illustrate in a general way the interpretation of plant
embryos which is outlined in the preceding pages. These diagrams which are more or less
schematic, represent sectional views of the various protocorms shortly after the differen-
tiation of the metacormal primordia. Haustral tissue is indicated by stippling. The
unstippled region represents in each case the sporophore primordium. The line extending
from the central region of the sporophore into the haustral tissue delineates the course of
the primary axis of the metacorm. In Fig. 8 to 11, the line across each diagram indicates
the juncture of protocormal and metacormal tissue. All of the tissue above this point is
originated by the metacormal meristems after their differentiation.

1. Anthoceros. 2. Phylloglossum. 3. Selaginella. 4. Pteris. 5. Zeamais. 6. Alisma.
7. Bursa. 8. Ginkgo. 9. Cycas. 10. Zamia. 11. Pinus.
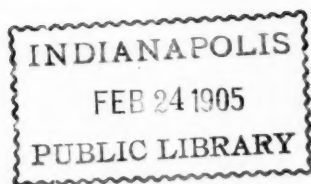
NOTES ON THE COMMENSALS FOUND IN THE TUBES OF *CHÆTOPTERUS PERGAMENTACEUS*.

H. E. ENDERS.

WHILE I was collecting *Chætopterus pergamentaceus* during the past summer on the shoals about Beaufort,[1] North Carolina, I became interested in the commensals which occur with this annelid, and their number and variety led me to study their habits.

These annelids, which grow in broadly U-shaped parchment tubes, are imbedded in diatomaceous, sandy shoals with from two to five centimeters of their free slender ends (about seven millimeters or less in diameter) protruding above the sand flats at or below low-tide level. These tubes serve as convenient temporary shelters for several species of small animals, and as the permanent abodes of others.

Of ninety-nine tubes collected and opened eleven were found without commensals while the remaining eighty-eight enclosed two annelids of the genus Nereis also one hundred and seventy-six crabs of the species [2] *Polyonyx macrocheles* (formerly *Porcellana macrocheles*), *Pinnixa chætopterana*, *Pinnotheres maculatus*, and one species of "stone crab," Menippe.[3] Polyonyx and Pinnixa are found either singly or together in the same tube, but usually in pairs, male and female, of a single species. Among the number of tubes collected seventy-five enclosed Polyonyx in pairs or singly (total 143); fifteen enclosed Pinnixa; two, Pinnotheres, and one, a "stone crab," Menippe, while two serpulids,

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[1] I am indebted to the Hon. Geo. M. Bowers, U. S. Commissioner of Fish and Fisheries, for the privilege of occupying a table in the Fisheries laboratory at Beaufort, N. C., and to Dr. Caswell Grave, the director, for courtesies shown.

[2] I am also indebted to Miss Mary J. Rathbun, of the U. S. National Museum, for the identification of the species of crabs.

[3] The specimen was mislaid or lost at Beaufort, N. C.

encrusted on a female Pinnixa, may be regarded as an accidental enclosure.

The tubes of Chætopterus are not the only abodes of some of the commensals named : Nereis is found among the shells, rocks and sea-weeds ; *Pinnotheres maculatus*, in the shells of *Pinna semi-nuda* like the related species, *P. ostreum*, in the oyster ; whilst Menippe commonly keeps in hiding in crevices and pits in rocks and shells. So far as I know, *Polyonyx macrocheles* and *Pinnixa chætopterana*, beyond the young stages, are only very *rarely* found free on the shoals, but *Polyonyx ocellata* is found at Beaufort on the body of Limulus, and sometimes in old shells dredged outside the harbor.

The sizes of the crabs range from two millimeters in width to that of the full-grown animal (thirteen to fourteen millimeters wide), and the smallest ones are of such a size that they could readily pass through the orifices of the tubes, and they probably do so for I have frequently collected tubes with two adult crabs and a single small one but rarely with three full-grown individuals.

The position of the crabs in the interior of the tubes I learned by keeping the Chætopterus and crabs in glass U-tubes, to the open ends of which the annelids constructed inverted parchment funnels, which prevented their escape. While the commensals move about with rapidity they remain at one end of the U-tube, usually the one opposite that occupied by the annelid itself, but when the annelid reverses its position they press past it to the opposite end and there remain bathed in the passing current. The annelids, Nereis, moved along the dorsal wall of the tube and did not interfere with Chætopterus which occupied the ventral portion of the tube.

The commensals, which are usually found near the orifices of the U-tube, are advantageously located for securing food, which, if it consists either of vegetable matter or of copepods and various larvæ which pass through the tube in the moderate current of water, and the worms that may seek shelter in the tube, is very abundant.

The commensals are permanently confined within the tubes of Chætopterus where the breeding is comparatively simplified

because of the presence, in nearly every instance, of male and female in the same tube. I also found tubes containing males only (4) or females only; among the latter the eggs on seven females (six Polyonyx and one Pinnotheres) thus taken were in various stages of development, while two other females had, just a short time before capture, liberated their broods. The mature male of Pinnotheres is small enough to pass into and out of the orifices of the tubes, but how or when the eggs of the isolated individuals of Polyonyx are fertilized remains an open question.

The breeding season of the two more common commensals, Polyonyx and Pinnixa, extends through the whole summer. Females with eggs in all stages of development, together with females which had just liberated their broods, were taken in my first collection, June 21st (1904), and even in my last collection, October 25th, every full-grown female taken bore developing eggs, or had very recently liberated her brood as shown by the few imperfect larvæ clinging to the pleopods, or by the position of the abdomen, or "apron," not being closely appressed to the body. At the time of the last collection the breeding season of Pinnixa must have been near its close but that of Polyonyx continued unabated.

The larvæ do not long remain in the tubes after they are hatched but soon find their way out and they may then be taken in the tow in considerable numbers from June till November.

Young crabs, not over two or three millimeters in width, are found in the tubes during the middle and latter parts of the breeding season, but they are frequently overlooked because of their tendency to press between the appendages or the folds of Chætopterus and hide there. In this manner four young crabs, about two millimeters wide, were overlooked when four tubes were opened, and from each the worm together with two full-grown commensals were removed, and only after the worms were submerged in the killing-fluid did the activity of the crabs make their presence known. Once in the tubes it is quite probable that the crabs remain there and are later prevented, through their own growth, from escaping.

The act of moulting was not observed in these commensals but recently moulted individuals of Polyonyx were taken on

three occasions, the "shells" of which, more or less nearly complete, were still in the same tube with the "soft-shelled" crabs.

When a worm in a tube dies the crabs in the same tube die as a result of the failure of food and properly aërated water. Two tubes were taken in which this might have occurred as was shown by the nearly perfect condition of the extremities of the tubes and by the presence of the bodies of three dead crabs lodged in the necks of the tubes, which were only recently filled with sand.

Whether or not commensalism is an advantage to Chætopterus it seems to be a decided benefit to the crabs, Polyonyx and Pinnixa, grown specimens of which are *rarely* found outside the tubes. The advantage to the crabs is very clearly marked by their prolonged breeding season — virtually an example of protected industry.

ON THE LARVA AND SPAT OF THE CANADIAN OYSTER.

JOSEPH STAFFORD.

UPON opening the Marine Biological Station of Canada for last summer's work the acting director, Professor Ramsay Wright, assigned to me the diagnosis of bivalve-larvæ occurring in the plankton.

The material was collected over the oyster-beds near Curtain Island, off Malpeque, P. E. I. Oyster-larvæ were first recognized on the 25th of July from which time they were present in the plankton collections until the 1st of Sept.

The free-swimming, pelagic larva of the oyster possesses a characteristic color, brownish-red — suggestive of the soil of its native island shores, a shade which enables it to be immediately distinguished from every other bivalve-larva with which it is associated. The shell is asymmetrical and inequivalve, the left valve being larger, more convex, and with a large umbo, the right smaller, flatter and with a moderate umbo. The umbos have a postero-dorsal position and project backwards and upwards, making the shell broader, deeper and squarer behind and tapering but rounded in front. The largest measure $.358 \times .365$ mm. in length and height, but the height and shape vary according to whichever side is turned towards the observer. Larvæ as small as $.131 \times .138$ mm. already possess the characteristic shape and color.

The internal structure of the larval oyster offers some interesting features. We have been accustomed to think of it as vastly different from other bivalve-larvæ, corresponding to the early assumption of a sessile mode of life. This misconception is due to lack of observation of plankton stages, embryologists having jumped from early veliger or phylembryo to late prodissoconch or even early nepionic periods.

When mounted on a slide the larvæ are accustomed to remain

quiescent and from their deep coloration are difficult to examine
but sometimes a more transparent one permits certain organs to
be traced.   When freshly collected and examined in a watch-glass
of pure sea-water many of them exhibit the greatest activity,
protruding the velum between the antero-ventral margins of the
shell, expanding it somewhat like opening an umbrella, and swim-
ming rapidly about by the violent movement of its cilia.   While
in motion the heavy shell is suspended below the expanded
velum.   Jarring the watch-glass will cause the animal to
instantly withdraw its velum, at the same time snapping the
valves of its shell together and dropping towards the bottom.
Upon again assuming activity it may protude a long, slim,
ciliated foot from the middle of its ventral surface, just behind
the velum.   The foot at this period is well developed and is a
most capable organ by means of which the animal can creep
rapidly about and forcibly flop its heavy shell from one side to
the other.   It can also bend up along the outside of the shell
and perform feeling movements over all parts of the body within
the shell.   Its lower or posterior surface sometimes appears
flattened or even grooved lengthwise and at a short distance
from the base of attachment to the body there is a heel-like pro-
jection which is doubtless the position of the byssus gland.   In
the proximal part of the foot, *i. e.,* about the center of the animal,
are right and left otocysts each containing about a dozen oto-
conia.   A little before and above these, but more superficial, are
two lateral, black pigment-spots (eye-spots).   Along each side,
past the base of attachment of the foot to the body, lies a series
of short gill-filaments, extending from the eye-spot backwards
and downwards to near the posterior margin of the shell ; in the
oldest free-swimming larvæ there are eight, diminishing in size
from before backwards, the last ones being mere knobs ; their
lower ends are free, but their upper ends spring from one con-
tinuous axis of origin, that, behind the foot, joins its mate of the
opposite side near the margins of the mantle.   The mouth and
œsophagus lie in the median plane immediately below and behind
the velum to which they are attached and with which they are
protruded and withdrawn.   In the quiescent animal the gullet
lies between velum and foot, in the median sagittal plane as well

as in, or very near, the median transverse plane of the body.
Here it passes dorsalwards, between the first gill-filaments, expanding into the stomach with its large lateral liver-sacs. The intestine passes backwards towards the right, and then forwards towards the left, when it again turns backwards and upwards in the left umbo, and finally downwards in the median plane, over the posterior adductor muscle ; the greater part of its folds lie in the larger, left valve. In front and above the velum is a transverse adductor muscle, while below the posterior parts of the umbos is a larger, transverse, posterior adductor muscle ; retractor fibers converge from the velum to points in the umbos. Right and left mantle-folds line the inner surfaces of the valves.

Examination of eel-grass, rock-weed and other marine plants, of shells, stones, sand and other objects, revealed no young spat. Bundles of brush were tied to submerged rocks, or weighted with stones and sunk at various places. These were carefully examined at intervals but without result. Window-glass was cut into strips 2×6 in. and stood on end in crocks, about a dozen in each held apart by wire racks, the crocks being then set out below low-water level on oyster beds and made secure by building stones around them. Daily examination of the glass was made until, on the 16th Aug., I found my first young oyster-spat. It measured $1.030 \times .876$ mm. in length and depth and exhibited the characteristic coloration of the pelagic larva. In the centre of its dorsal surface could be distinctly recognized the shell (prodissoconch) of the oldest free-swimming stage. ($.384 \times .369$ mm.), securely fixed to the glass by its left valve. The anterior adductor appeared to be moved slightly backwards and upwards from its original position, and the posterior adductor had moved downwards and backwards to a position outside the border of the prodissoconch. Behind it opened the rectum. In front of the adductors and in a direction parallel with them, slanting downwards and backwards, were the axes of two sets of gill-filaments, the deeper (left) of sixteen long filaments with their free ends pointing forwards or forwards and downwards, the upper (right) of about half that number of short filaments that ceased below the posterior adductor muscle. No foot could be recognized. The new spat shell was very thin and

delicate, its prisms easily separating from each other at the margins, while beyond these at places the mantle was sometimes protruded.

Three other spat oysters were procured on glass in the same way, the dates and sizes being : Aug. 19, 1.20 × 1.58 mm.; Aug. 22, .55 × .51 mm. ; Aug. 31, .953 × .861 mm.

Search was made daily for spat on natural marine objects and on Sept. 2nd I found the first, on the outer surface of a half-grown oyster shell. It measured 2.3 × 2.4 mm., but instead of having a pink, red, or brown coloration as one would suspect from comparison with the larval or earliest spat stages ; or, instead of having a chalky-white appearance as one would judge from comparison with the old oysters ; it presented a shining, dark metallic lustre with a few faint radial lines. From this time onwards they were to be found in increasing numbers, and, after being once shown them, the deck hands of the government steamer Ostrea could also find them. Altogether I have observed spat oysters on the shells of the oyster, mussel, clam, quohog, bar-clam, razor-clam, round whelk, and on stones. The objects with which they may be most easily conflicted are the young of *Crepidula fornicata* and colonies of *Ralfsia verrucosa*. At the time of leaving Malpeque, Sept. 20, the largest this year's spat I had seen measured 6 mm. in height, had a dark steel lustre, radiating ridges or lines, and very thin edges ; the whole oyster being thin and fitting so solidly against the supporting .shell as to require some force with a knife-blade to separate it.

As to the rate of growth my 4th spat oyster on glass was obtained Aug. 31, when it measured .953 × .861 mm. and had about sixteen gill-filaments. On Sept. 7 it measured 1.261 × 1.276 mm. and had about twenty-four gill filaments. A week later it measured 1.661 × 1.753 mm. One might say that it doubled its length and height in two weeks. The smallest oysters were about the size of one's thumb nail. I have put out wire baskets containing numbers of selected, half-grown, living oysters, having black spat attached, to be examined next spring.

MONTREAL, 23 Dec. 1904.

A TABLE TO FACILITATE THE DETERMINATION OF THE MEXICAN SCALE-INSECTS OF THE GENUS ASPIDIOTUS (*SENS. LATISS.*)

T. D. A. COCKERELL.

Of all the Coccidæ injurious to cultivated plants, none are more easily carried to new countries, or more likely to cause trouble, than the species of Aspidiotus, *sens. latiss* (including Chrysomphalus, etc.). Some years ago I prepared for my own use a table of the Mexican forms of this group which were known to be or likely to prove of economic importance, using only characters which could be determined with a hand lens. This table is now presented with the hope that it will be useful to those who have to deal with injurious Coccidæ. The determination from the scale should of course always be confirmed by reference to a detailed account of the insect ; but in the majority of cases, at least, the indications of the table will be found correct.

♀ scale elongated . . . . 1.
♀ scale circular or subcircular . . . . 2.
1. ♀ scale linear, 2½ mm. long, ⅔ mm. broad. (on mango, Frontera)
          longissimus Ckll.
    ♀ scale much broader (on cactus, Frontera) . . *bowreyi* Ckll.
2. ♀ scale minute, less than 1 mm. diam., black or very dark brown or gray . . . . 3.
    ♀ scale ordinary . . . . 4.
3. ♀ scale very convex, exuviæ covered, marked by a ring (on various plants) . . . . *personatus* Comst.
    ♀ scale broad pyriform, first skin exposed (on mesquite, Hermosillo)
          prosopidis Ckll.
4. Scale dark with orange or copper-red exuviæ . . . . 5.
    Scale white or light colored, with darker exuviæ . . . 8.
    Scale blackish or brown, with concolorous or darker exuviæ . 14.
    Scale pale or reddish, with concolorous exuviæ . . . . 19.
5. Exuviæ lateral, at one end of the oval scale ; scale black with more or less grayish and whitish concentric strigation ; exuviæ deep orange (Cuautla)
          dentilobis Ckll.

45

Exuviæ central or nearly so . . . . 6.

6. Scale hardly 1½ mm. diam., exuviæ deep reddish (on oak, Amecameca)
ancylus Putnam.

   Scale 2 mm. or over in diameter . . . . . . 7.

7. Scale slightly raised, the exuviæ coppery, nipple-like (on many plants)
aonidum (L.)

   Scale very flat, exuviæ flat, not nipple-like, large, pale orange (on *Citrus*, etc.) . . . . *scutiformis* Ckll.

8. Exuviæ light yellow or orange . . . . . 9.

   Exuviæ at least partly brown or black . . . . . 10.

9. Exuviæ covered (Coahuila) . . . . *townsendi* Ckll.

   Exuviæ exposed (on various plants) . . *hederæ* var. *nerii*, Bouché.

10. First skin black or dark brown, second orange (Salina Cruz.)
tricolor Ckll.

   The exuviæ practically all of one color . . . . . 11.

11. Small, about 1 mm. diam., exuviæ covered, only conspicuous when
rubbed, then shining dark brown or black (on Yucca, Coahuila)
yuccæ Ckll.

   Larger, exuviæ conspicuous without rubbing . . . . 12.

12. Scale convex (on various plants) . . . *acuminatus* Targ.

   Scale flat . . . . 13.

13. Scale very dark brown, covered with a chalky-white secretion (on
orange, Cuernavaca) . . . . *albopictus* Ckll.

   Scale grayish, border more or less whitish (on orange, Linares)
albopictus var. *leonis* Twns. & Ckll.

14. Exuviæ not conspicuous . . . . . . 15.

   Exuviæ black or very dark. conspicuous . . . . . 17.

15. Scale light brown (Frontera) . . . *jatrophæ* Twns. & Ckll.

   Scale very dark . . . . 16.

16. Scale convex, dark gray (on mimosa, Tampico) . *mimosæ* Comst.

   Scale flat, dark brown . . . . . . *perseæ* Comst.

17. Scale covered by the epidermis of the tree, the shining black exuviæ
alone exposed (Orizaba) . . . . . . *calurus* Ckll.

   Scale exposed . . . . 18.

18. Scales 3 mm. diam. (San Luis Potosi) . . *nigropunctatus* Ckll.

   Scales 1 to 1½ mm. diam. (on Agave, Toluca) . *agavis*, Twns. & Ckll.

19. Scale rather convex, exuviæ nearly marginal (on grape-vine) *crawii*, Ckll.

   Scale flat or flattish, exuviæ not nearly marginal . . . 20.

20. Scale light brown, exuviæ not marked by a dot and ring (Tehuantepec
City) . . . . *reniformis*, Ckll.

   Exuviæ marked by a dot and ring . . . . . 21.

21. Scale light reddish brown (on various plants) . *dictyospermi*, Morg.

   Scale darker (on Citrus, Oaxaca) . . *koebelei*, Twns. & Ckll.

BOULDER, COLORADO.

NOTES AND LITERATURE. ·

GENERAL BIOLOGY.

Lloyd and Bigelow's Teaching of Biology.[1]— In the joint volume by Professors Lloyd and Bigelow, on the teaching of biology in the secondary schools, the first half of the book, under the sub-title "The Teaching of Botany and Nature Study," comprising some 320 odd pages divided into ten chapters, is by Professor Lloyd. The style, while at times a little abrupt, is convincing and forceful, and much sound common sense is inculcated in this presentation of the subject. The introductory chapter is of the nature of a general exposition of the value of science in education and of the sciences the especial value of biology. The author brings out clearly the importance of biological training, not only from the facts which it teaches, but also, what is more essential, the discipline which it affords. The nature study side of the question is first considered since that subject is first demanded in the schools at the present time. Here we find strong arguments for the necessity of intellectual honesty and against that curse of nature study, sentimentalism. The pitfalls which lie in the way of teachers, in the confusion of teleological and causal interpretations of organic structures, are dwelt upon.

The subject of botany itself is begun in the following chapter and the various aspects of the subject developed in the subsequent ones. The greatest interest perhaps centers in the discussion of the different types of botanical courses. Every modern botanist must agree with the author in his advocacy of a dynamic point of view, rather than the formal morphological one which arises from a lack of a proper consideration of the physiological side of the subject. While the necessity of some study of types is recognized, very cogent and just criticisms are made of the extreme "type course," criticisms, indeed, which apply not only to biology as taught in schools, but also as taught in colleges.

The starting point for a botanical course will always be a moot

[1] Lloyd, F. E. and Bigelow, M. E. *The Teaching of Biology in the Secondary Schools.* New York, Longmans. 1904. American Teachers Series. 8vo, viii + 491 pp.

question and must necessarily depend in a measure on the individual
teacher and the conditions under which he works. Here the fruit
is advocated as the point of departure, from which the student natu-
rally passes to the study of the seed and seedling, till finally the fully
developed plant and its organs are all taken up. In connection with
the necessary morphological and anatomical study, the physiology
and, to an adequate extent, the ecological relations of the plant, are
brought out. The author's attitude towards ecology will be appre-
ciated by many, for without in any sense undervaluing its interest
and importance he subordinates it so that it is not made the only
end and aim of botanical instruction. The consideration of types
follows, but the transition seems a little abrupt from what has gone
before. Whether, in the time usually available in schools, the stu-
dents could with advantage study such obscure forms as Myxomy-
cetes, must be a question.

The value of the book as a whole, to teachers, particularly to those
who have not had the advantage of adequate preparation, cannot
but be great. It is essentially not a book which deals with fads,
the importance of nature study under the conditions which exist is
recognized without exaggerating this importance, the use of botanical
instruction proper in higher schools is justified with reasonable mod-
eration. The attitude of the author towards essential questions is
wholesome and stimulating. While enthusiasm of the best kind is
strongly advocated, sentimentalism is frowned upon, honesty of
thought and of observation is insisted upon. The dynamic point of
view, already referred to, that plants should be considered as living
organisms and not merely as aggregations of cells and tissues
arranged in interesting patterns, or as objects to be placed in hard
and fast categories, will undoubtedly serve to stir up those who tend
to fall into a too formal conception of botany ; and the need of such
stimulus when the great mass of botanical instruction the country
over is considered, is probably almost as great as ever. Another
point of value is the warning against unreasoning acceptance of
teleological and causal interpretations, which bring about false con-
ceptions of the significance of structures. The great value of the
book then is in this plain straightforward attitude and the desire to
avoid and show others how to avoid, question begging ideas of form
and of function. As to the particular form of a botanical course for
secondary schools it is not necessary to assume any finality in the
arrangement suggested, nor is it necessary for the teacher to follow
exactly the plan adopted, to be able to get a very useful stimulus
from the book.

Practical notes as to laboratory equipment and so forth, conclude Professors Lloyd's part of this volume and it should also be mentioned that at the head of each chapter copious and usually pertinent references are given to articles and books which the reader may desire to consult.

The second part of the book, entitled "The Teaching of Zoölogy in the Secondary Schools," covers some 248 pages arranged under twelve chapters, and is by Professor Bigelow. In the first chapter the aims of zoölogical teaching are discussed from the standpoint of the secondary school and emphasis is laid on the importance of zoölogy as a means of training the mind as well as an informational subject. In discussing available matter for zoölogy Professor Bigelow advocates a partial return to the study of internal anatomy, including dissection, from which in the last ten years the secondary schools have tended to withdraw. It is questionable whether this proposal is sound, for, notwithstanding laboratory pretensions, the teacher of zoölogy is bound to impart most of his knowledge by authoritative statement rather than by demonstration and hence he may draw his laboratory material from the many illustrations in external anatomy rather than from internal dissection so often objectionable to the pupil.

The importance of animal ecology, classification, embryology, palæontology, and evolution are reasonably urged but with the final apology that perhaps these aspects of zoölogy, good in themselves, are for want of time not possible in the school. If, however, we understand Professor Bigelow aright the pupil is not to be treated in such a way as to bring him to the state of a "finished" product at the end of his school life, but he is to be turned out with a mind trained for mental work and awakened by a flood of suggestions that will lead him in later years to take an active interest in the intellectual life about him. From this standpoint few subjects are more important than ecology, palæontology, and evolution.

Good advise based upon actual experience is contained in the chapter on laboratory method, and the advantages of the "verification" and "investigation" methods are set forth so well that even the strongest advocates of the latter must see that theirs is not the only path to true knowledge. The conception of school "physiology" as a special application of zoölogy and its importance in connection with this science is justly emphasized and ought to lead to a radical reform and betterment in the teaching of this subject. The zoölogical text, like that of the botanical portion, is accompanied by copious

references and list of books, a feature which alone makes the volume of great importance to the teacher.

One feature in the present situation of biological teaching is apparently not dwelt upon and that is the importance of high grade teachers for such work.   Doubtless this is taken for granted, but it is certainly too true that the subjects included under biology are often forced as side work upon uninterested teachers with the result that the poor outcome is too frequently attributed to the subject rather than to the conditions under which it is taught.   As a whole the volume is an unusually sound body of suggestion and advise which no teacher of school biology can afford to be without.

<div align="right">R. & P.</div>

ZOÖLOGY.

A New Textbook of Zoögeography.[1] — Professor Arnold Jacobi of the Forestry Academy at Tharandt, Saxony, has lately published a small manual.   It is with much pleasure and satisfaction that we have read this little work, since it is the first general treatise of the subject which pays due attention to the modern improved ideas with regard to zoögeographical methods.

While all previous textbooks on this subject generally fall more or less in line with Wallace's method, giving chiefly an account of the present conditions of animal distribution upon the earth's surface, and being satisfied with the creation of a " scheme " of animal distribution, Jacobi makes it the fundamental idea of his book, that the creation of " schemes of distribution " is not the final goal of zoögeographical research, but only a means to facilitate it.   He adopts the view that no scheme whatever is able to explain all cases, that it is possible to create different schemes for different groups of animals, and that even then there are exceptional cases, which need further research.   That these exceptional cases very often find their explanation in the geological history of the particular group to which they belong, is also maintained by him, and he most emphatically declares this latter study the most important branch of this science.   Thus he fully accepts the general principles of zoögeography as set forth repeatedly by Ortmann.

The limited space alloted for the work made it impossible for the

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[1] Jacobi, A.   *Tiergeographie* (Sammlung Goeschen).   Leipzig, 1904.   12°. 152 pp., 2 maps.

author to give more than a mere sketch. But in this short sketch is condensed a wealth of information that is of highest value for the student. Only a few words shall be said here to direct attention to the chief features of the book.

The whole is divided in three main divisions : the *first part*, introduction, contains the discussion of general principles, part of which has been mentioned above. The two other parts are entitled : *General Zoögeography*, and *Special Zoögeography*. The *former* treats (in 9 chapters) of the general laws of animal distribution, the relation of the range of animals to space, the means of dispersal and barriers to it, the struggle for space, the difference between centre of origin, areas occupied later on, and areas of survival. Further, the principal physical conditions of life and conditions of dispersal are discussed, and finally certain typical cases of distribution are selected as examples for the laws laid down.

The *last part*, Special Zoögeography (17 chapters), contains first a short historical sketch of the work done previously in this line. Then follows a discussion of the schemes proposed for the division of the earth in zoögeographical unites, a discussion of the scheme accepted in this work (for continental life), and a sketch of the actual distribution of selected groups of animals (Mammals, Birds, Reptiles, Amphibians, Freshwater Fishes, Insects, Land Snails, Earthworms). The last chapter treats of marine life and the laws of distribution governing it.

It is only to be regretted that the author did not have an opportunity to more fully discuss certain points, and chiefly, to go into detail with regard to the geological development of the present condition of animal distribution : but lack of space explains this. Another exception might be taken with reference to the scheme accepted for the distribution of land animals : but since this point is to a degree a matter of personal taste with the author, we shall not discuss it here.

<div align="right">A. E. O.</div>

Watchers of the Trails.[1]— Prof. C. D. G. Roberts' latest collection of animal stories, *The Watchers of the Trails*, does not fulfill the promise of his earlier *Kindred of the Wild*. It suggests rather the endeavor to work up the poorer ore from a once rich vein. We can not be expected to follow the fortunes of a dragon-fly larva with the same interest that held us in the story of the bull-moose, the "King

[1] Roberts, C. G. D. *The Watchers of the Trails.* Boston. L. C. Page & Co. 1904. 8vo, pp. 161. With many illustrations by Charles Livingstone Bull.

of the Mamozekel." The only distinctly new point of view in the volume under discussion is the study of domestic breeds in a wild environment. "The Alien of the Wild," describes the fortunes of a bull who is born and reared in the wilderness. London has however already entered this field in *The Call of the Wild*.

In Prof. Roberts' earlier volume there is an interesting essay on the evolution of the animal story, a sort of *confessio religionis* of the literary naturalist. We quote two sentences. "They [the naturalists of the new school] are minutely scrupulous as to their natural history, and assiduous contributors to that science. But above all they are diligent in their search for the motive beneath the action." It is significant that Prof. Roberts, to judge from this essay, seems unac quainted with the school of which Hudson (*The Naturalist in La Plata*), and Belt (*Naturalist in Nicaragua*) are noteworthy examples. The present volume contains a prefatory note in which Prof. Roberts replies briefly to the charge, made by Burroughs, "of ascribing to my animals human motives and the mental processes of man." This prefatory note is an important contribution to the literature of the animal story controversy, inasmuch as it reveals the fundamental difference in temperament between the scientist and the literary artist. Prof. Roberts claims that a boyhood spent at the edge of a great wilderness .fits a sensitive, sympathetic nature to portray wild life truthfully. It certainly has fitted him to call up in his fellow-men the mood which he himself experiences in the forest gloom. It does not necessarily fit him to tell us how the animals themselves feel. Whether in this particular volume, he has always, as he claims, been at particular pains to guard against ascribing motives on insufficient evidence, it is impossible to prove one way or the other. But when we read (p. 140) that all the wild kindred near a lumber-camp, which had spoiled their hunting, despised the camp dog as a renegade and traitor, and that they would have felt more satisfaction in taking vengeance on him than on his masters, we wonder how Prof. Roberts knows their minds so intimately. That the dog was killed by a wild-cat seems to have been the only fact in his possession. He says that the wild-cat went off, "elated from his vengeance." Most juries of scientists would, we fear, sustain Mr. Burroughs' charges.

For Prof. Roberts' skill as a literary artist we have a great admiration. His story of "The Truce," in the present volume is a thoroughly admirable piece of work. The book is richly illustrated by Charles Livingstone Bull.

Shells of Land and Water.[1] — This work is a diversion from the usual type of conchological publications, the author endeavors to popularize the study of the mollusks by a narrative. A quartette consisting of a professor and three students, take various trips to the "homes" of the land, fresh-water and marine species; these trips are supplemented by frequent visits to the museum, thus in a general way all of the more important groups are studied. Their first excursion is to the "home" of the fresh-water clam, then a day with the snails of the pond, river and brook, followed by a visit to the museum. The homes of the land snails are next invaded and the evening is spent in the snailery. The next chapter is "how snails eat" with figures of radula, jaws, etc. To study the exotic forms the museum is again visited. In the same manner the marine forms are studied, with instructions for dredging and preserving specimens. The work closes with "some books to study" and a glossary of technical terms.

The book contains 175 pages, the illustrations in the text, of which there are upwards of 150, are excellent and well selected, while the eight colored plates are beautiful examples of the three color process; the work is also embellished by six half-tone plates from photographs showing the homes of the various mollusks. To those taking up the study of conchology as a pastime the work is admirably adapted.

<div align="right">C. W. J.</div>

BOTANY.

Pfeffer's Plant Physiology. — The completion of the second edition of Pfeffer's *Pflanzen physiologic*[2] is a significant event. Ten years ago Pfeffer began the revision which has just been completed. It would have been finished earlier but for the continued ill health of the author. Pfeffer's aim, as pointed out in reviews of the parts which have previously appeared,[3] has been to present the science as

[1] Baker, F. C. *Shells of Land and Water. A familiar Introduction to the Study of Mollusks.* Chicago, Mumford, 1903. 8vo, xii + 262 pp., 215 figs.

[2] Pfeffer, W. *Pflanzenphysiologie. Handbuch der Lehre vom Stoffwechsel und Kraftwechsel in der Pflanze.* 2 te Auflage, 2 vols., Leipzig, Engelmann, 1897–1904.

[3] *American Naturalist,* vols. XXXII, pp. 450–1, 1898, and XXXVI, pp. 594–5, 1902.

it is at present, to separate fact from theory, to examine each hypothesis, discarding the false and emphasizing the probably true. Besides the enormous amount of reading required, Pfeffer and his assistants have done a great deal of experimental work, testing in his own laboratory the work and conclusions reported by others. The result is a critical mastery, on Pfeffer's part, of the whole subject of plant physiology, such as no other man possesses, and the fruit of this mastery is his book. The book, in presenting the science as it now is, shows what is known and thought, how much more this is than when the first edition was published nearly twenty-five years ago; it shows also how indefinite our knowledge is, how inadequate our thoughts, and how limited the field of investigation has hitherto been. As remarked in a previous review, the plant physiology of to-day is the result of the study of higher plants mainly. The lower plants have been more carefully studied by physiologists during the last five years than ever before. The results of this study are evident and valued. When the physiology of these plants is understood even to the extent to which we now understand the physiology of higher plants, plant physiology will bear a different aspect from what it does to-day. In the second as in the first edition, Pfeffer divides his subject into *Stoffwechsel* and *Kraftwechsel*. To these classical headings a third is now sometimes added, *Farmwechsel*. Though this last is but a special aspect, a special result, of the other two, it is a result which will certainly become increasingly important as it becomes increasingly evident from the experimental investigation of simpler plants.

From Pfeffer's book it is clear that the study of the influence of the various factors of the environment upon the form of living organisms stands, in results, far behind our knowledge of these factors upon the immediate behavior of living organisms. In this last part of the *Handbuch* we have mainly the subject of movements. These are examined in detail. The mechanics of movement are better understood than the action of the stimulus upon the living organism, but in both cases the phenomena are so complicated and often so contradictory in different forms that it is impossible to make a general statement of the subject which would be both clear and truthful. For this reason this part of Pfeffer's book possesses in the extreme those qualities for which the earlier parts have been most severely criticised, *viz.*, lack of definite summary statements, repetitions, and minute argumentative criticism. Summary statements which would be true cannot now be made. Repetition is unavoid-

able because of the original division of the subject, but it is always a repetition from a different standpoint, giving the reader a more comprehensive view of the subject. And only by minute criticism of what has been published is it possible to distinguish fact from theory, and well-founded theory from that which is only plausible.

This book will serve as the basis, the inspiration, and the critical guide of the investigations of the next twenty years. The future is not likely to give us another book by one man who is master of the whole field. This book stands as a monument to Pfeffer's learning. The books which follow it will be written by several masters working together, as is already the case in animal physiology.

It may not be out of place to mention here that the Philosophical Faculty of the University at Göttingen have awarded the 12,000 mark prize of the Otto Vahlbruck Foundation to Pfeffer, justly considering his *pflanzenphysiologic* the most worthy contribution to botanical science which has been made in years.

The excellent English translation by Ewart, the first two parts of which have appeared,[1] will be cordially welcomed when completed.

G. J. P.

[1] Published by the Clarendon Press, Oxford.

CORRESPONDENCE.

Editor of the American Naturalist.

Sir : — I have only recently seen in the *American Naturalist* for July–August the review of a revision of Professor Orton's *Comparative Zoölogy* which I prepared and which was issued last year by the American Book Company. As the reviewer makes certain very erroneous implications I am led to send this communication with the request that you permit it to appear in the *Naturalist.*

About ten years ago at the request of Mrs. Orton I made a revision of Professor Orton's *Comparative Zoölogy* which was published by Harper and Brothers. In this edition it was impracticable to reset the book, and all new matter, except verbal changes, was placed in an appendix. This edition, I understand, is still in use in some schools and is known as Orton's *Comparative Zoölogy,* revised by myself.

More recently, at the request of the American Book Company and with the cordial approval of Mrs. Orton, I prepared the edition which is the subject of the review mentioned. This revision was undertaken largely for the purpose of meeting the wishes of certain schools that desired to continue using Professor Orton's book but felt the necessity of introducing practical work, of following a more modern system of classification, and of having a more logical arrangement of the text than the earlier edition afforded. When deciding upon the title for the new revision the publishers contended that it must be so worded as to avoid the confusion which would inevitably arise in the schools and in the trade if the two editions bore the same title, it being their intention to continue the publication of the earlier revision. For this reason the name was changed to *General Zoölogy, Practical, Systematic, and Comparative. Being a Revision and Re-arrangement of Orton's Comparative Zoölogy,* a title which fully describes the character of the book. From the letters which passed between the publishers and myself regarding the title, I quote from one concerning a form of title-page which was submitted to me but which I rejected because it did not express fully enough the fact that the present edition claims to be nothing more than a revision. "As to having my name standing practically alone

as the author of the book, I have very strong conscientious scruples against it. The book, even as it stands, is really Orton's work, for I have added only a comparatively small amount, and I do not want to appear to have appropriated another man's book. But this, I fear, is just how it will look unless Orton's name is given, as it deserves, more prominence on the title-page. If I had re-written the book, then we might say, perhaps, 'Based on Orton's Comparative Zoölogy,' but, as matters stand, the book *is Orton's Comparative Zoölogy*, with some changes and additions of my own, to be sure, but they are hardly sufficient in number or importance to warrant me in assuming to have made such a radical change as to justify my being called the author." In the same letter I suggested that in order to avoid confusing the two editions the trade name for the new one might be the "Orton-Dodge General Zoölogy." The first printing of the book was sent out without Professor Orton's name on the cover, a most unfortunate error and one which no one regrets more deeply than I do, but the omission was made without my consent or knowledge and I am in no way responsible for it. The publishers promptly corrected the mistake at the next printing of the volume.

In justice to the American Book Company I wish to state also that to the best of my knowledge the advertising matter sent out regarding the book has never represented it to be "a *new* one," as the reviewer would have us believe. I have carefully examined all of the several catalogues, folders, etc., in my possession and all state that this is "a revision and re-arrangement of Orton's Comparative Zoölogy," and describe fully the extent and character of the changes made. Furthermore, in various expressions attention is called to this fact no fewer than three times in a preface of less than that number of pages. It is, consequently, a most preposterous supposition that anyone can be misled as to the nature of the book.

Finally, if, in spite of all efforts to the contrary, I have not made my position clear, I will say for the sake of those who may be interested in the matter that I deny most emphatically the implication that I have or have had any desire, intention, or expectation to receive credit which properly belongs to Professor Orton, my sometime predecessor in this institution.

Very truly yours,

CHARLES WRIGHT DODGE.

UNIVERSITY OF ROCHESTER.